Chapter 2
Topographic Accuracy Standards

2-1. General

This chapter sets forth the accuracy standards to be used in USACE for topographic mapping. The mapping accuracy standards are associated with the scales and sheet size of the finished map. Horizontal accuracy is directly related to the map scale. Vertical accuracy is a stated fraction of the contour interval. The contour interval is related to the vertical scale. Details of these map accuracies are stated in this chapter. The map standards set forth in this chapter shall have precedence over numbers, figures, references, or guidance presented in other chapters. USACE topographic surveying and mapping criteria are detailed in Table 2-1. Upon selection of the type of project to be mapped the criteria limits are specified. The specific map scale and contour interval within these limits are selected according to specific project parameters. Survey accuracies needed to achieve these map accuracies are separate issues and are addressed in Chapter 3.

a. Mapping standards. A map accuracy is determined by comparing the mapped location of selected well-defined points to their "true" location as determined by a conventional field survey. A map accuracy standard classifies a map as statistically meeting a certain level of accuracy. Horizontal (or planimetric) map accuracy standards are usually expressed in terms of two-dimensional radial positional error measures -- the root mean square (RMS) statistic. Vertical map accuracy standards are in terms of one-dimensional RMS elevation errors. Map accuracy classifications are dependent on the specified (i.e., designed) target scale and vertical relief, or contour interval, of the map. Reference EM 1110-1-1000 and the FGCS Multipurpose Land Information System Guidebook for more detailed information.

b. Surveying standards. All maps warranting an accuracy classification must be referenced to, or controlled by, conventional field surveys. The surveying standards are independent of these map accuracy standards -- survey accuracies based on relative closure estimates cannot necessarily be correlated with map accuracy positional error estimates. Survey accuracy is a function of the specifications and procedures used, the resultant internal or external closures, and is independent of the map scale or map contour interval. The accuracy of the conventional field survey used to test the map accuracy must exceed that of the map.

c. Target scale and contour interval specifications. Mapping accuracy standards are associated with the final development scale of the map, both the horizontal "target" scale and vertical relief (specified contour interval) components. Photogrammetric mapping flight altitudes or ground topographic (topo) survey accuracy and density requirements are specified based on the design map target scale and contour interval. The use of Computer Aided Drafting and Design (CADD) or Geographic Information Systems (GIS) equipment allows planimetric features and topographic elevations to be readily separated onto various layers and depiction at any scale. Problems arise when target scales are increased beyond their original values, or when so-called "rubber sheeting" is performed. Therefore, it is critical that these spatial data layers contain descriptor information identifying the original source target scale and designed accuracy.

2-2. Topographic Mapping Standards

There are six generally recognized industry standards which can be used for specifying spatial mapping products and resultant accuracy compliance criteria.

- Office of Management and Budget (OMB) United States National Map Accuracy Standards.
- American Society of Photogrammetry (ASP) Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways.
- U.S. Department of Transportation (DOT) Surveying and Mapping Manual Map Standards.
- American Society of Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large Scale Maps.
- American Society of Civil Engineers (ASCE) Surveying and Mapping Division Standards.
- U.S. National Cartographic Standards for Spatial Accuracy.

Each of these standards has applications to different types of functional products, ranging from wide-area small-scale mapping (OMB National Map Accuracy Standards) to large-scale engineering design (ASPRS Accuracy Standards for Large Scale Maps). Their resultant accuracy criteria (i.e., spatial errors in X, Y, and Z), including quality control compliance procedures, do not differ significantly from one another. In general, use of any of these standards will result in a quality map.

Table 2-1
USACE Surveying and Mapping Requirements for Military Construction, Civil Works, Operations, Maintenance, Real Estate, and Hazardous, Toxic, and Radioactive Waste (HTRW) Projects

Project or Activity	Typical Target (Plot) Map Scale[1] 1 in = X ft	Feature Location Tolerance[2] (feet-RMS)	USACE Control Survey[3] Accuracy	Feature Elevation Tolerance[4] (feet-RMS)	USACE Control Survey[5] Accuracy	Typical Contour Interval (feet)	ASPRS Map Accuracy Class
MILITARY CONSTRUCTION (MCA, MCAF, OMA, OMAF):							
Design & Construction of New Facilities: Site Plan Data for Direct Input into CADD 2D/3D Design Files							
General Site Plan Feature and Topo Detail	30-50 ft	0.1-0.5 ft	3rd - I	0.1-0.3 ft	3rd	1 ft	1 or 2
Surface/Subsurface Utility Detail	30-50 ft	0.2-0.5 ft	3rd - I	0.1-0.2 ft	3rd	n/a	1
Building or Structure Design	20-50 ft	0.05-0.2 ft	3rd - I	0.1-0.3 ft	3rd	1 ft	1
Airfield Pavement Design Detail	20-40 ft	0.05-0.1 ft	3rd - I	0.05-0.1 ft	2nd	0.5-1 ft	1
Grading and Excavation Plans (roads, drainage, etc.)	30-100 ft	0.5-2 ft	3rd - I or II	0.2-1 ft	3rd	1-2 ft	2
Maintenance & Repair (M&R), or Renovation of Existing Structures, Roadways, Utilities, etc.; for Design/Construction Plans and Specifications (P&S)	30-50 ft	0.1-0.5 ft	3rd - I	0.1-0.5 ft	3rd	1 ft	1
Recreational Site P&S: (Golf Courses, Athletic Fields, etc.)	100 ft	1-2 ft	3rd - II	0.2-2 ft	3rd	2-5 ft	2
Training Sites, Ranges, Cantonment Areas, etc.	100-200 ft	1-5 ft	3rd - II	1-5 ft	3rd	2 ft	2 or 3
Installation Master Planning & Facilities Management Activities (Including AM/FM and GIS Feature Applications)							
General Location Maps; for master planning purposes	100-400 ft	2-10 ft	3rd - II	1-10 ft	3rd	2-10 ft	2 or 3
Space Management (interior design/layout)	10-50 ft	0.05-1 ft	Relative to Structure	n/a	n/a	n/a	n/a

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Table 2-1
(Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] 1 in = X ft	Feature Location Tolerance[2] (feet-RMS)	USACE Control Survey[3] Accuracy	Feature Elevation Tolerance[4] (feet-RMS)	USACE Control Survey[5] Accuracy	Typical Contour Interval (feet)	ASPRS Map Accuracy Class
Installation Surface/Subsurface Utility Maps (As-builts; fuel gas, elec, comm, cable, storm water, sanitary, water supply, treatment facilities, meters, etc.)	50-100 (DA) 50 ft (USAF)	0.2-1 ft	3rd - I	0.1 ft	3rd	1 ft	1
Architectural Drawings (Reference ER 1110-345-710):							
Floor Plans, Roof Plans, Exterior Elevations, Cross Sections	1/16" to 1/4" per ft	-	-	-	-	-	-
Wall Sections	1/2" per ft	-	-	-	-	-	-
Stair Details	3/4" per ft	-	-	-	-	-	-
Detail Plans	3/4" to 3" per ft	-	-	-	-	-	-
Area/Installation/Base-Wide Mapping Control Network to Support Overall GIS & AM/FM Development[6]	n/a	varies 1-200 ft	3rd - I or 2nd - II	varies 1-10 ft	2nd or 3rd	1-10 ft	2 or 3
Housing Management (Family housing, schools, boundaries, and other installation community services)	100-400 ft	10-50 ft	4th	n/a	4th	n/a	3
Environmental Mapping & Assessments	200-400 ft	10-50 ft	4th	n/a	4th	n/a	3
Emergency Services (Military police, crime/accident locations, emergency transport routes, post security zoning, etc.)	400-2,000 ft	50-100 ft	4th	n/a	4th	n/a	3
Cultural, Social, Historical (Other natural resources)	400 ft	20-100 ft	4th	n/a	4th	n/a	3
Runway Approach & Transition Zones; General Plans/Sections[7]	100-200 ft	5-10 ft	3rd-II	2-5 ft	3rd	5 ft	2 or 3
<u>**CIVIL WORKS DESIGN, CONSTRUCTION, OPERATIONS, AND MAINTENANCE ACTIVITIES:**</u>							
Site Plan Mapping for Design Memoranda, Contract Plans & Specifications, etc. -- for Input to CADD 2D/3D Design Files							
Locks, Dams, Flood Control Structures; Detail Design Plans	20-50 ft	0.05-1 ft	2nd - II	0.01-0.5 ft	2nd or 3rd	0.5-1 ft	1

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Table 2-1
(Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] 1 in = X ft	Feature Location Tolerance[2] (feet-RMS)	USACE Control Survey[3] Accuracy	Feature Elevation Tolerance[4] (feet-RMS)	USACE Control Survey[5] Accuracy	Typical Contour Interval (feet)	ASPRS Map Accuracy Class
Grading/Excavation Plans	100 ft	0.5-2 ft	3rd - I	0.2-1 ft	3rd	1-5 ft	1
Spillways, Concrete Channels, Upland Disposal Areas	50-100 ft	0.1-2 ft	2nd - II	0.2-2 ft	3rd	1-5 ft	1
Construction In-place Volume Measurement	40-100 ft	0.5-2 ft	3rd - I	0.5-1 ft	3rd	n/a	1
River & Harbor Navigation Projects: Site Plan Mapping Design, Operation, or Maintenance of Flood Control Structures, Canals, Channels, etc. -- for Contract Plans or Reports							
Levees & Groins (new work or maintenance design drawings)	100 ft	1-2 ft	3rd - II	0.5-1 ft	3rd	1-2 ft	2
Canals & Waterway Dredging (new work base mapping)[8]	100 ft	2 ft	3rd - II	0.5 ft	3rd	1 ft	3
Canals & Waterway Dredging (maintenance drawings)	200 ft	2 ft	3rd - II	0.5 ft	3rd	1 ft	3
Beach Renourishment/Hurricane Protection Projects	100-200 ft	2 ft	3rd - II	0.5-1 ft	3rd	1 ft	2
Project Condition Reports: (Base mapping for plotting hydrographic surveys -- line maps or airphoto plans)	200-1,000 ft	5-50 ft	3rd - II	0.5-1 ft	3rd	1-2 ft	3
Revetment Clearing, Grading, & As-built Protection	100-400 ft	2-10 ft	3rd - II	0.5-1 ft	3rd	1-2 ft	3
Geotechnical & Hydrographic Site Investigation Surveying Accuracies:							
Hydrographic Contract Payment and P&S Surveys	-	10 ft	n/a	0.5 ft	n/a	1 ft	n/a
Hydrographic Project Condition Surveys	-	20 ft	n/a	1.0 ft	n/a	1 ft	n/a
Hydrographic Reconnaissance Surveys	-	300 ft	n/a	1.5 ft	n/a	1 ft	n/a
Geotechnical Investigative Core Borings	-	5-10 ft	4th	0.1-0.5 ft	3rd or 4th	1-5 ft	n/a
General Planning & Feasibility Studies, Reconnaissance Reports, Permit Applications, etc.	100-400 ft	2-10 ft	3rd - II	0.5-2 ft	3rd	2-10 ft	3

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Table 2-1
(Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] 1 in = X ft	Feature Location Tolerance[2] (feet-RMS)	USACE Control Survey[3] Accuracy	Feature Elevation Tolerance[4] (feet-RMS)	USACE Control Survey[5] Accuracy	Typical Contour Interval (feet)	ASPRS Map Accuracy Class
Civil Works Projects -- GIS Feature Mapping:							
Area/Project-Wide Mapping Control Network to Support Overall GIS Development	n/a	Varies 1-100 ft	2nd - I or 2nd - II	Varies 1-10 ft	2nd	1-10 ft	2 or 3
Soil & Geologic Classification Maps, Well Points	400 ft	20-100 ft	4th	n/a	4th	n/a	3
Cultural & Economic Resources, Historic Preservation	1,000 ft	50-100 ft	4th	n/a	4th	n/a	3
Land Utilization GIS Classifications; Regulatory Permit General Locations	400-1,000 ft	50-100 ft	4th	n/a	4th	n/a	3
Socio-Economic GIS Classifications	1,000 ft	100 ft	4th	n/a	4th	n/a	3
Land Cover Classification Maps	400-1,000 ft	50-200 ft	4th	n/a	4th	n/a	3
Archeological or Structure Site Detail Mapping (including non-topographic - close range - photogrammetric mapping)	0.5-10 ft	0.01-0.5 ft	2nd - I or II	0.01-0.5 ft	2nd	0.1-1 ft	1
Structural Deformation Monitoring Studies/Surveys:[9]							
Reinforced Concrete Structures (locks, dams, gates, intake structures, tunnels, penstocks, spillways, bridges, etc.)	Large-scale vector movement diagrams	0.001 ft	n/a[10]	0.001 ft	n/a[11]	(Long-Term Movement) 0.01-0.1 ft	n/a
Earth/Rock Fill Structures (dams, floodwalls, levees, etc.)	or tabulations	0.01-0.2 ft	n/a	0.01-0.1 ft	n/a	0.1 ft	n/a
Flood Control & Multi-Purpose Project Planning, Floodplain Mapping, Water Quality Analysis & Flood Control Studies	400-1,000 ft	20-100 ft	3rd - I	0.2-2 ft	2nd or 3rd	2-5 ft	3
FEMA Flood Insurance Studies	400 ft	20 ft	3rd - I	0.5 ft	3rd	4 ft	3

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Table 2-1
(Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] 1 in = X ft	Feature Location Tolerance[2] (feet-RMS)	USACE Control Survey[3] Accuracy	Feature Elevation Tolerance[4] (feet-RMS)	USACE Control Survey[5] Accuracy	Typical Contour Interval (feet)	ASPRS Map Accuracy Class
REAL ESTATE ACTIVITIES (ACQUISITION, DISPOSAL, MANAGEMENT, AUDIT)[12]							
Tract Maps, Individual: Detailing installation or reservation boundaries, lots, parcels, adjoining parcels & record plats, utilities, etc.	20-400 ft[13]	0.05-2 ft	3rd-I or II	0.1-2 ft	3rd	1-5 ft	1
Condemnation Exhibit Maps	20-400 ft	0.05-2 ft	3rd-I or II	0.1-2 ft	3rd	1-5 ft	1
Guide Taking Lines (for fee & easement acquisition) **Boundary Encroachment Maps**	20-100 ft	0.1-1 ft	3rd-I or II	0.1-1 ft	3rd	1 ft	1
Real Estate GIS or LIS General Feature Mapping: Land Utilization & Management, Forestry Management, Mineral Acquisition	200-1,000 ft	50-100 ft	4th	n/a	4th	n/a	3
General Location or Planning Maps	1:24,000 (USGS)	50-100 ft	n/a	5-10 ft	3rd	5-10 ft	-
Easement Areas and Easement Delineation Lines	100 ft	0.1-0.5 ft	3rd - I or II	0.1-0.5 ft	3rd	-	2
HAZARDOUS & TOXIC WASTE (HTW) SITE INVESTIGATION, MODELING, & CLEAN-UP ACTIVITIES							
General Detailed Site Plan Mapping (HTW sites, asbestos, etc.)	5-50 ft	0.2-1 ft	2nd - II	0.1-0.5 ft	2nd or 3rd	0.5-1 ft	1
Subsurface Geotoxic Data Mapping (Modeling)	20-100 ft	1-5 ft	3rd - II	1-2 ft	3rd	1-2 ft	1
Contaminated Groundwater Plume Mapping (Modeling)	20-100 ft	2-10 ft	3rd - II	1-5 ft	3rd	1-2 ft	2

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Table 2-1
(Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] 1 in = X ft	Feature Location Tolerance[2] (feet-RMS)	USACE Control Survey[3] Accuracy	Feature Elevation Tolerance[4] (feet-RMS)	USACE Control Survey[5] Accuracy	Typical Contour Interval (feet)	ASPRS Map Accuracy Class
General HTW Site Planning, Reconnaissance Mapping, etc.	50-400 ft	2-20 ft	3rd - II	2-20 ft	3rd	2-5 ft	2

EMERGENCY OPERATION MANAGEMENT ACTIVITIES (Use basic GIS database requirements defined above)

1. Target map scale is that contained in CADD, GIS, and/or AM/FM layer, and/or to which ground topo or aerial photography accuracy specifications are developed. This scale may not always be compatible with the feature location/elevation tolerances required -- in many instances, design or real property features are located to a far greater relative accuracy than that which can be scaled at the target (plot) scale, such as property corners, utility alignments, first-floor or invert elevations, etc. Coordinates/elevations for such items are usually directly input into a CADD or AM/FM database.

2. The map location tolerance (or precision) of a planimetric feature is defined relative to two adjacent points within the confines of a structure or map sheet, not to the overall project or installation boundaries. Relative accuracies are determined between two points which must functionally maintain a given accuracy tolerance between themselves, such as adjacent property corners, adjacent utility lines, adjoining buildings, bridge piers or approaches or abutments, overall building or structure site construction limits, runway ends, catch basins, levee baseline sections, etc. The tolerances between the two points are determined from the end functional requirements of the project/structure (e.g., field construction/fabrication, field stakeout or layout, alignment, locationing, etc.). Few engineering, construction, or real estate projects require that relative accuracies be rigidly maintained beyond a 5,000-foot range, and usually only within the range of the detailed design drawing for a project/structure (or its equivalent CADD design file limit). For example, two catch basins 200 feet apart should be located to 0.1 foot relative to each other, but need only be known to ±100 feet relative to another catch basin 5 miles away. Likewise, relative accuracy tolerances are far less critical for small-scale GIS, LIS, and AM/FM data elements. Actual construction alignment and grade stakeout will generally be performed to the 0.1- or 0.01-foot levels, depending on the type of construction.

3. USACE control survey accuracy refers to the procedural and closure specifications needed to obtain/maintain the relative accuracy tolerances needed between two functionally adjacent points on the map or structure, for construction or layout. Usually 3rd-Order control procedures (horizontal and vertical) will provide sufficient accuracy for most work, and in many instances of small-scale mapping or GIS rasters, 3rd-Order - Class II methods and 4th-Order topo/construction control methods may be used. Base or area-wide mapping control procedures shall be designed and specified to meet functional accuracy tolerances within the limits of the structure, building, or utility distance involved for design, construction, or real estate surveys. Higher Order control surveys shall not be specified for area-wide mapping or GIS definition unless a definitive functional requirement exists (e.g., military operational targeting or some low-gradient flood-control projects).

4. See Note 2. Some flood-control projects may require better relative accuracy tolerances than those shown.

5. See Note 3.

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Table 2-1
(Concluded)

6. GIS raster or vector features generally can be scaled or digitized from any existing map of the installation -- typically a standard USGS 1 inch = 2,000 foot scale quadrangle map is adequate given the low relative accuracies needed between GIS data features, elements, or classifications. Relative or absolute GPS positioning (10 to 300 feet) may be adequate to tie GIS features where no maps exist. In general, a basic area or installation-wide 2nd- or 3rd-Order control network is adequate for all subsequent engineering, construction, real estate, GIS, and/or AM/FM control.

7. Typical requirements for general approach maps are 1:50,000 (H) and 1:1,000 (V); detail maps at 1:5,000 (H) and 1:250 (V).

8. Table refers to base maps upon which subsurface hydrographic surveys are plotted, not to hydrographic survey control.

9. Long-term structural movements measured from points external to the structure may be tabulated or plotted in either X-Y-Z or by single vector movement normal to a potential failure plane. Reference EM 1110-2-4300 and EM 1110-2-1908 for stress-strain, pressure, seismic, and other precise structural deflection measurement methods within/between structural members, monoliths, cells, embankments, etc.

10. Accuracy standards and procedures for structural deformation surveys are contained in EM 1110-1-1004. Horizontal and vertical deformation monitoring survey procedures are performed relative to a control network established for the structure. Ties to the NGRS or NGVD 29 are not necessary other than for general reference; and then need only USACE 3rd-Order connection.

11. See Note 10.

12. Real property surveys shall conform to local/state minimum technical standards where prescribed by law or code.

13. A 1 inch = 100 foot scale is recommended by ER 405-1-2. Smaller scales should be on even 100-foot increments.

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2-3. USACE Topographic Mapping Standard

The recommended standard for USACE topographic mapping is the ASPRS Accuracy Standards for Large Scale Maps. This standard was developed (and is generally recognized) by the photogrammetric industry. The associated scale is defined for maps larger than 1:20,000 (1 inch = 1,667 feet). The scale range of most USACE large-scale topographic work is 1 inch = 10 feet to 1 inch = 200 feet. Maps for flood control and emergency services may have smaller scales. Topographic surveys in support of architectural drawing details may have larger scales. The ASPRS standards contain definitive statistical map testing criteria which can be used to truth a map. Tangible information for contract administration may be documented in a contract based on these testing criteria. For USACE small-scale maps the OMB United States National Map Accuracy Standards are used. USACE map scales for these standards are less than or equal to 1:20,000. Maps generated at these scales will generally be flown by aerial photography. For details of this standard consult EM 1110-1-1000.

2-4. Intended Use of the Map

Table 2-1 depicts recommended scales, contour intervals, and all associated position tolerances for USACE projects or activities. Functional activities are divided into military construction, civil works, real estate, hazardous waste, and emergency management. Sub-activities for each of these categories define the necessary map parameters. Use of Table 2-1 saves preliminary mapping research and establishes standards for USACE mapping requirements. Standards are especially important due to the high demand of digital data information. For most projects, identification of the type of project is the only design assumption required. The USACE mapping parameters are selected across the appropriate row. The remaining sections of this chapter list criteria for narrowing a map design parameter for cases in Table 2-1 where a range is allowable. Map clarity, map cost, and map sheet size are considerations for narrowing parameter ranges to specific numbers in each category for a given project.

2-5. Area of the Project

Location of points in a large area may be measured with consistent precision throughout, but the relative precision of the points located furthest from the control will tend to have more error than points located directly from control monuments. In order to maintain the required accuracy for a project, a primary project control net or loop is established to cover the entire project. Secondary project control loops or nets are constructed from the primary project network. This helps to ensure that the intended precision will not drop below the tolerance of the survey. In lieu of increasing control requirements, the map scale may be reduced. This trade-off between survey control and scale has either increased project costs or the scale has been reduced below usable limits in some cases. To resolve the trade-off problem, the ASPRS has stated the map accuracy relative to the finished map sheet. This substitutes relative survey line accuracies between points in the national network for relative survey line accuracies between points contained within the sheet borders. Map recipient requirements are met per sheet, which is usually the purpose of the majority of site plan mapping used in construction.

2-6. Map Scale

Map scale is the ratio of the distance measurement between two identifiable points on a map to the same physical points existing at ground scale. The errors in map plotting and scaling should exceed errors in measurements on the ground by a ratio of about 3 to 1. Stated in a different manner, a ratio can be established as a function of the plotter error divided by the allowable scale error. For example, if a digital plotter has an accuracy of ±0.25 mm and scaled map distances must be accurate to ±0.5 foot (152 mm), then 0.25/152 = 1/610; or the ratio becomes 1:600 or 1 inch = 50 feet.

a. Another common number used by surveyors to determine map scales and survey precision is an error of 1/40 inch (0.64 mm) between any two points scaled from the finished map. This error is assumed constant regardless of the length of a line until the scale is changed. For example, given a scale error of 1/40 inch and a feature accuracy requirement of ±10 feet, the maximum allowable map scale would be 1/40 inch / 10 feet, or a scale of 1 inch = 400 feet.

b. The traditional 1/40-inch plotting/scaling error probably originated from the National Map Accuracy Standard (NMAS). The NMAS specified not more than 10% of well-defined points (a group sample) tested in the field on a given map shall be in error by more than 1/30 inch (85 mm) for scales greater than 1:20,000 (large-scale). Not more than 10% of points tested shall be in error exceeding 1/50 inch (50 mm) for scales equal to or smaller than 1:20,000. These measurements were tested at the publication scale for horizontal map truthing. Vertical map truthing specified not more than 10% of the elevations tested will exceed one-half the contour interval.

1/100 inch (0.25 mm) is the maximum error for a (one) plottable well-defined point, easily visible or recoverable on the ground, as defined by the NMAS. Note that the smaller the sample size, the more restrictive becomes the tolerance. This is why 20 points are required in the ASPRS standard. To compute the NMAS Circular Map Accuracy Standard (CMAS) from the ASPRS values, use the following conversion:

$$CMAS = 2.146 * \sigma_{x \text{ or } y}$$

c. The ASPRS standard emphasizes that the standard is based at full ground scale and the CMAS can only approximately be compared to the 1/30 inch NMAS.

d. The surveyor should always use the smallest scale which will provide the necessary detail for a given project. This will provide economy and meet the project requirements. Use this rule-of-thumb when deciding limits as provided in Table 2-1. Once the smallest scale has been selected from Table 2-1, determine if any other map uses are possible for this project which need a larger scale. If no other uses are of practical value, then the map scale has been determined.

2-7. Contour Interval

The contour interval is the constant elevation difference between two adjacent contour lines. The contour interval is chosen based on the map purpose, required vertical accuracy (if any was specified), the relief of the area of concern, and somewhat the map scale. Steep slopes (large relief) will cause the surveyor to increase the contour interval in order to make the map more legible. Flat areas will tend to decrease the interval to a limit which does not interfere with planimetric details located on the topographic map.

a. As a general rule, the lower limit for the contour interval is 25 lines per inch for even the smallest map scales. The checklist to find the proper contour interval is:

(1) Intended purpose of the map.

(2) The desired accuracy of the depicted vertical information.

(3) Area relief (mountainous, hilly, rolling, flat, etc.).

(4) Cost of extra field work and possibility of plotting problems for selecting a smaller contour interval.

(5) Other practical uses for the intended map.

b. Following the above checklist, contour interval ranges are recommended in Table 2-1 for the types of projects typically encountered in USACE. If a specific vertical tolerance has been specified as the purpose for the mapping project, then the contour interval may be determined as a direct proportion from Table 2-1 for the type of project site. Otherwise, the stated map accuracy of the vertical information will be in terms of the selected contour interval within the limits provided by Table 2-1.

c. Any contour drawn on the map will be correct to a stated fraction of the selected contour interval. Because interpolation is used between spot elevations, the spot elevations themselves are required to be twice as precise as the contours generated by the spot elevations.

2-8. ASPRS Accuracy Standards

a. USACE has adopted the ASPRS accuracy specifications for large-scale mapping. The maps are divided into three classes. Class 1 holds the highest accuracies. Site plans for construction fit this category. Class 2 has half the overall accuracy of Class 1. Typical projects may include excavation, road grading, or disposal operations. Class 3 has one third the accuracy or three times the allowable error of Class 1 maps. Large area cadastral, city planning, or land classification maps are typically in this category. The ASPRS map class selection is listed for each activity or project type. Tables 2-2 and 2-3 detail ASPRS horizontal and vertical accuracy requirements, respectively.

Table 2-2
Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Feet) for Well-Defined Points

Target Map Scale		Limiting RMS Error in X or Y, ft ASPRS		
1 in.= x (ft)	Ratio ft/ft	Class 1	Class 2	Class 3
5	1:60	0.05	0.10	0.15
10	1:120	0.10	0.20	0.30
20	1:240	0.2	0.4	0.6
30	1:360	0.3	0.6	0.9
40	1:480	0.4	0.8	1.2
50	1:600	0.5	1.0	1.5
60	1:720	0.6	1.2	1.8
100	1:1,200	1.0	2.0	3.0
200	1:2,400	2.0	4.0	6.0
400	1:4,800	4.0	8.0	12.0
500	1:6,000	5.0	10.0	15.0
800	1:9,600	8.0	16.0	24.0
1,000	1:12,000	10.0	20.0	30.0
1,667	1:20,000	16.7	33.3	50.0

Table 2-3
ASPRS Topographic Elevation Accuracy Requirement for Well-Defined Points

	ASPRS Limiting RMS Error, ft					
	Topo Feature Points			Spot or DTM[1] Elevation Points		
Target Contour Interval (ft)	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
0.5	0.17	0.33	0.50	0.08	0.16	0.25
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5

[1] DTM = digital terrain model.

b. A limiting root mean square error (RMSE) for each class is indicated in Tables 2-2 and 2-3. The RMSE is found by locating prominent features by rectangular coordinates from a finished planimetric or topographic map. At least 20 check points are measured from the map. The points are selected in an agreement between the map producer and the client. A survey party then locates the same points on the ground. Third-Order survey methods are sufficient in most cases, depending again on the map scale and the area of the project. The survey methods used for map testing must be superior to the methods used to construct the map in order to establish a truth basis.

c. To test horizontal features, planimetric coordinates of well-defined points are scaled from the finished map in ground scale units and subtracted from the same actual coordinates obtained during the field check survey. The test checks the x and y directions separately. The planimetric coordinate differences are inspected for any discrepancies exceeding three times the limiting RMSE according to class in Table 2-2. If more than 20 points were selected for the check survey, the discrepancies in excess of three times the RMS may be thrown out; but the entire point must be discarded (x,y,z). Outlier values existing in a minimum data set of 20 must be resolved in the field. Outlier values are considered blunders and shall be resolved before an ASPRS accuracy statement is printed on the finished map. The discrepancies are squared. The squares are summed and divided by the number of points used for the sample. The square root operation is performed on value obtained from the sum of the squared differences divided by the sample number to obtain the RMSE test statistic. This same procedure is then performed for the Y and Z coordinates.

d. Table 2-2 lists the planimetric feature coordinate accuracy requirements for well-defined points in either the X coordinate or Y coordinate directions. The values in the columns under the classes are in ground units of feet. The values are at ground scale, not map scale. An accuracy statement in the notes of each map sheet shall be published stating the finished map meets the USACE requirement for location of planimetric features at the published scale. The RMSE is computed for each map sheet produced and compared to Table 2-3 according to map class and target map scale.

e. The values of the RMSE differences are inversely proportional to the map scale. As the map scale decreases, the limiting RMSE in the differences increases. The increase in the allowable tolerance includes the total errors of survey control, data collection, map compilation/ plotting, and scaling errors in depicting well-defined points from the finished map. The limiting accuracies listed in Table 2-2 are the maximum permissible RMSE allowed under the ASPRS standard. Work performed by experienced topographic survey crews should be well within the limits of the values in Table 2-2. As stated above, the RMSE is computed from a sample of no less than 20 well-defined points. Whether or not this acceptance testing is actually performed is a contracting officer determination -- not all map products need to be tested. If the test is performed correctly and the map cannot meet the requirements of Table 2-2, the accuracy statement cannot be published in the notes until the map has been corrected by the map producer.

f. A vertical accuracy statement shall be included in the notes section of each map sheet produced for the USACE, based on the ASPRS map class and contour interval shown in Table 2-3. The check used to meet the class requirement is based on the RMSE and tolerance limits of Table 2-3. Table 2-3 lists two types of values based on a given contour interval. The first group of values to the left of the table correspond to topographic map features and the allowable vertical error in the finished map. These features may be roads, buildings, trees, hilltops, swales, valleys, or creeks. The values to the right side are allowable errors for spot locations which are actual topographic locations where a measurement was taken. Spot locations require half the allowable error of their corresponding feature points for a given contour interval.

2-9. USACE Horizontal Accuracy Check

Note 2 of Table 2-1 explains horizontal map accuracy in terms of relative accuracies of structures critical to engineering or construction objectives. This is the intention of most mapping produced in USACE. For construction applications, a minimum of three pairs of points (total of six points) should be tested per map sheet. These points should be located in the construction area and be intended for length and orientation of significant existing structures. The planimetric features used for identifying pairs on a finished map will be man-made well-defined points.

a. Field locations of well-defined project points are recorded such that distances can be chained at the time of the survey. The procedures used are typical of a building location survey. Coordinates are computed for the locations and checked against the chained distances to ensure that blunders or systematic errors are minimized.

b. The same points are scaled or digitized in the office from the finished map sheet. For each of the six points, a delta x and delta y are computed. Taking the six points two at a time generates a combination of 15 errors from the map sheet. Calculation of the 15 errors is easily done on a computer. The computation should be performed in terms of latitude and departure instead of distance alone. The sum of the squares of the latitude and departure errors will result in an RMSE for comparison with the tolerances shown in Table 2-1.